Effect of leaf litter mulching on the pests of tomato

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Abstract: Agricultural techniques essentially change the weed flora, pests and diseases of cultivated plants. Our aim was to investigate the effect of leaf litter mulch on the pests of tomato, especially on the weed flora and on three important plant protection problems: late blight (*Phytophthora infestans*), cotton bollworm (*Helicoverpa armigera*) and root-knot nematodes (*Meloidogyne* spp.). Besides mulching, the experiment consisted of irrigation, mycorrhiza-inoculation and artificial *Meloidogyne*-infestation. We recorded the natural *P. infestans* infection, *Helicoverpa armigera* damage and the species composition and cover of weeds as well. We examined whether leaf litter mulching had any effect on pests, and on the generative and vegetative production of tomato. Our results were that only mulching had a significant positive effect on almost all the measured generative and vegetative production parameters of tomato, while irrigation, mycorrhiza application and artificial nematode infestation had no significant effects on these parameters. Negative correlation was found between *P. infestans* infection and *H. armigera*-damage on tomato fruits. Mulching also reduced significantly the number of *Meloidogyne*-induced galls on the roots of tomato. Application of leaf litter mulch did not affect soil organic matter and soil pH within the growing season. In the beginning of the growing season mulching suppressed weed cover. Later, there was no significant difference between weed cover in the treatments. It can be concluded that leaf litter mulch had a more pronounced influence on the quantity of yield than on the damage and presence of pests and weeds.

Keywords: *Meloidogyne* sp., leaf litter mulching, *Phytophthora infestans,* tomato, weed

Introduction

Mulching is multifunctional: it is able to regulate the nutrient level, porosity, temperature and water management of the soil (Balázs 1989). Moreover, mulching hampers weed emergence therefore contributes to decreasing the frequency of weeding, irrigation and nutrient supply (Makkai 2008).

The role of organic mulching in weed control is much more important in the beginning of the growing season than later. Peat, chopped wheat straw and woodchips successfully suppressed weed germination. Grass clippings were also effective, but only before starting to decompose. When decomposition started, it had not any effect on weeds (Jodaugienė et al. 2006).

Straw-mulching and mechanical weed control resulted in a different composition of weed flora than the tillage-based method. Furthermore, mulching was more effective to control weeds. The straw mulching could suppress most of annual weeds, but it was also effective especially in the case of the sturdier, perennial species (Zalai et al. 2015).

In the case of newspaper-mulching, a 7.6 cm thick layer of chopped newspaper suppressed 90 % of weeds and conserved soil moisture. However, thicker newspaper-mulching resulted in a reduced soil temperature (Monks et al. 1997).

Examining the effect of polyethylene mulch on *Phytophthora infestans* on tomato, it suppressed the disease more effectively than fungicides (Shtienberg et al. 2010). Oat straw mulch negatively correlated with *Phytophthora cinnamomi* in the case of avocado (You and Sivasithamparam 1995). Researchers found that different kinds of animal manure and fresh green manure reduced the viability of oospores and the incidence of

DOI: 10.18380/SZIE.COLUM.2016.3.2.35

Phytophthora capsici (Núñez-Zofío et al. 2011). In case of potato, arbuscular mycorrhiza induced systemic resistance, decreased the leaf infection by *P. infestans* (Gallou et al. 2011).

The use of newspaper mulching decreased the number of nematodes *(Pratylenchus penetrans)*, and thus reduced nematode damage in apple (Forge et al. 2008).

When mulched with plastic, especially with black plastic, tomato plants produced significantly higher number of fruits and the weight of fresh fruit per plant was also significantly higher. In addition, black plastic decreased root-knot nematode *(Meloidogyne javanica)* infestation (Ogwulumba and Ugwuoke 2011).

Our aim was to investigate the effect of leaf litter mulching on the yield and on the pests of tomato, especially on weed cover and on the presence and damage of *P. infestans*, *Helicoverpa armigera* and *Meloidogyne* species. Besides mulching, the experiment consisted of irrigation, mycorrhiza-inoculation and artificial *Meloidogyne*-infestation.

Materials and methods

Biological materials

The experiment took place on the trial field of Szent István University in Gödöllő. The tomato seeds („Dány” gene bank sample) were provided by Plant Diversity Center, (Növényi Diverzitás Központ, NöDiK), with the help of Research Institute of Organic Agriculture (Ökológiai Mezőgazdasági Kutatóintézet, ÖMKi).

The „Dány” gene bank sample is a determinate type of tomato. Its fruit is bright red coloured, round-shaped with 75- 85 g average fruit weight. The disease-resistance of the variety is medium (Cseperkálóné Mirek et al. 2014).

Artificial infestation was used to introduce root-knot nematodes *(Meloidogyne* spp.). The inoculum was collected from polytunnel raised peppers, in Jászfényszaru. It contained spontaneously infested root pieces and soil.

The mycorrhiza inoculation was obtained by using SYMBIVIT® that contains the following species*: Glomus claroideum, G. etunicatum, G. geosporum, G. intraradices, G. microaggregatum* and *G. mosseae* (Albrechtova et al. 2011). Since these species were all renamed after issuing the permission for marketing of SYMBIVIT®, their recent scientific names are: *Claroideoglomus claroideum, Claroideoglomus etunicatum, Funneliformis geosporum, Rhizophagus intraradices* (Schüßler and Walker 2010)*, Rhizoglomus microaggregatum* (Sieverding et al. 2014) and *Funneliformis mosseae* (Schüßler and Walker 2010). Leaf litter was used as a mulching material, and it was provided by Zöld Híd Régió

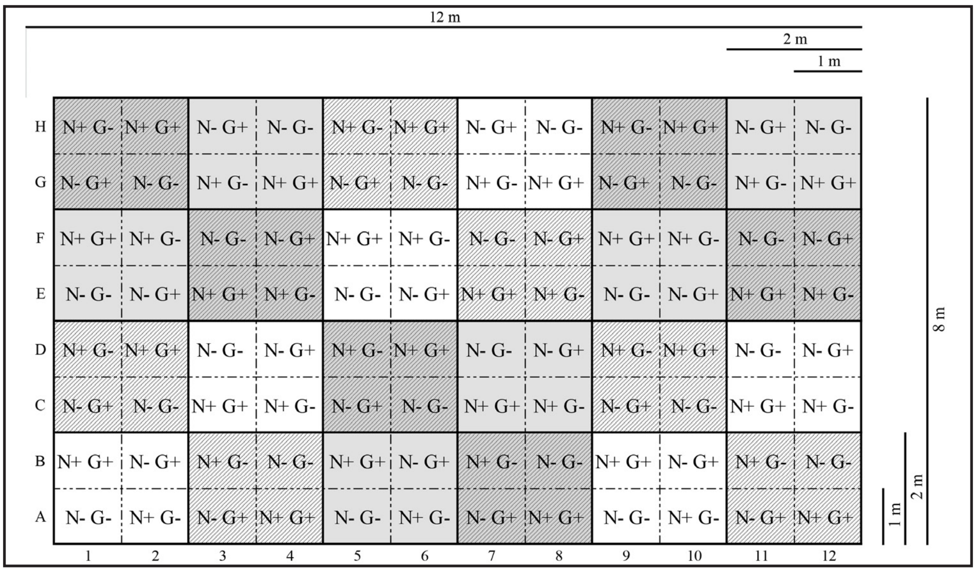

Figure 1. Arrangement of treatments
(N: Root-knot nematode, G: *Glomus*, Greycolored: Irrigation, Lined: Mulching).

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Ltd. It consisted mostly of the leaves of maples (*Acer* spp.). The leaf litter was collected in Gödöllő in October 2015, and was stored in open field circumstances as a pile (without any handling or processing) approximately 60 m far from the experimental plots until application as mulch in June 2016. Thickness of mulch was 15 cm at the beginning of the experiment.

<u>*Interaction experiment*</u>

On 18 March, a frame was made from pinewood to separate the various treatments. Altogether, there were 24 pieces of 2 x 2 m plots on a 96 m^2 total area. After the pinewood-frame was in place, leaf litter was spread on every second plots. Tomato seeds were sown on 14 April into potting compost. After 2 weeks, the seedlings were planted into pots. On 2 June, before planting, we weeded the area. After weeding, leaf litter mulch and a dripping irrigation system was installed, and all the irrigated plots were given dripper stakes. So there were four treatments and six replications of the 24 plots:

1. mulched and irrigated (M+I+)
2. mulched and non-irrigated (M+I-)
3. unmulched and irrigated (M-I+)
4. control unmulched and non-irrigated (M-I-)

In every plot, 4 plants were planted (1 plant/m^2), and every single plant received a different treatment within each plot:

1. control (N-G-) (after the terms "Nematode" and "*Glomus*")
2. only *Meloidogyne*-infested (N+G-)
3. only mycorrhiza-inoculated (N-G+)
4. both *Meloidogyne*-infested and mycorrhiza-inoculated (N+G+).

In case of mycorrhiza-inoculation, 25 g SYMBIVIT® product was used, as described on the instruction of the producer. To reach the planned *Meloidogyne* infestation, 20 g infested soil with pieces of galled roots were placed under the roots of tomato plants during planting. (For the *Meloidogyne* infestation not J2 nematodes (Hooper et al. 2005) were used, because our opinion was that although the number of nematodes are known in that way, but the juveniles can get easily injured during the extraction process. Therefore they may lose their virulence. On the other hand, we can achieve a more realistic inoculation with infested soil and galled root pieces.)

Altogether, 16 treatment combinations with 6 replications were used in a combined block

Table 1. Values of scales elaborated by Zeck (1971), Garabedian and Van Gundy (1984), Mukhtar et al. (2013) (modification of Taylor and Sasser 1978) for estimation of root-knot nematode (*Meloidogyne* spp.) damage on roots.

Scale-values	Zeck (1971)	Garabedian and Van Gundy (1984)	Mukhtar et al. (2013) (mod. Taylor and Sasser 1978)
0	no galls	no infection	0 gall
1	very few small galls	1-20% infection (trace)	1- 2 galls
2	numerous small galls	21-40% infection (slight)	3- 10 galls
3	numerous small galls, some of which are grown together	41-60% infection (moderate)	11- 30 galls
4	numerous small and some big galls	61-80% infection (severe)	30- 70 galls
5	25% of roots severely galled	81-100% infection (very severe)	71- 100 galls
6	50% of roots severely galled		> 100 galls
7	75% of roots severely galled		
8	no healthy roots but plant is still green		
9	roots rotting and plant dying		
10	plant and roots dead		

setting (Figure 1). As there was a rainy period at the beginning of summer, irrigation started only on 20 June. Daily weather dataset was the basis to calculate the optimal irrigation quantities (Helyes and Varga 1994). Irrigated blocks were supplied with water three times a week. In case of rain, irrigation quantity was corrected with the quantity of the rainfall. During the whole growing season, 153 mm water was used for the irrigation treatment, while 213 mm rain fell.

From 13 July, the formation of the generative parts were observed and noted. In case of every observation, quantity of the formed bunches, flower buds, flowers and later, fruits were recorded. On 8 of August, the height of the plants and the widest diameter of their canopies were measured.

During the growing season, weeding was done after every weed survey (26 May, 27 June, 18 July, 5 August and 28 August). The plots were weeded and hoed, and the demand of time for weeding and the species composition of weed flora was recorded for every plot. The early symptoms of tomato late blight *(Phytophthora infestans)* were noticed on 2 August. In order to reduce the spreading of the disease, Trifender *(Trichoderma asperellum)* and Boni Protect *(Aureobasidium pullulans)* were sprayed. Besides *P. infestans* infection, the tomato fruits were damaged by the larvae of the cotton bollworm *(Helicoverpa armigera).* Infected and damaged fruits were removed and measured. The experiment was terminated on 30 August. The tomato yield was measured. Soil samples were collected from the root zone. After washing the roots, *Meloidogyne* damage was estimated with the help of the scales elaborated by Zeck (1971), Garabedian and Van Gundy (1984), Mukhtar et al. (2013) (modification of Taylor and Sasser 1978) (Table 1). Finally, fresh shoots and roots were measured. After 2 weeks of air-drying, dry weight of shoots and roots were measured as well.

<u>*Laboratory examinations*</u>

In order to identify the *Meloidogyne* species in the inoculum from Jászfényszaru, a preparation method by Hartman and Sasser (1985) was used. 10 individuals of female root-knot nematodes were examined for species determination. A revised version (Szakálas et al. 2015) of Baermann funnel (Baermann 1917) was used to extract active nematodes from

Table 2. Generative production parameters of tomato plants receiving the following treatments: unmulched and mulched (M), non-irrigated and irrigated (I), non-infested and artificially nematode-infested (N), non-inoculated and artificially mycorrhiza-inoculated (G). (p-value: Welch test)

	Mulching (M)		Irrigation (I)		Root-knot nematode (N)		Glomus (G)	
treatment -/+	-	+	-	+	-	+	-	+
number of repetitons	48	48	48	48	48	48	48	48
Maximum number of bunches/plant								
mean ± CI 95%	18.5 ± 1.4	27.8 ± 1.9	22.4 ± 2.2	23.8 ± 2.1	22.5 ± 2.3	23.7 ± 2	22.9 ± 2.2	23.4 ± 2.1
p-value	**< 0.001**		0.373		0.45		0.767	
Maximum number of buds/plant								
mean ± CI 95%	22.5 ± 2	31.5 ± 2.7	27.5 ± 2.5	26.5 ± 2.8	26.6 ± 2.7	27.4 ± 2.6	27.06 ± 2.3	26.9 ± 3
p-value	**< 0.001**		0.612		0.658		0.94	
Maximum number of flowers/plant								
mean ± CI 95%	25.7 ± 2.6	39.4 ± 3.4	29 ± 3.7	36 ± 3.3	31.3 ± 3.8	33.8 ± 3.3	32.1 ± 3.5	33 ± 3.7
p-value	**< 0.001**		**0.006**		0.341		0.719	
Total number of fruits/plant								
mean ± CI 95%	16.4 ± 2	31.9 ± 3.8	25.4 ± 4.1	23 ± 3.4	24.3 ± 3.9	24.1 ± 3.7	24.1 ± 4.1	24.2 ± 3.4
p-value	**< 0.001**		0.368		0.945		0.982	

DOI: 10.18380/SZIE.COLUM.2016.3.2.35

Table 3. Vegetative production parameters of tomato plants receiving the following treatments: unmulched and mulched (M), non-irrigated and irrigated (I), non-infested and artificially nematode-infested (N), non-inoculated and artificially mycorrhiza-inoculated (G). (p-value: Welch test)

	Mulching (M)		Irrigation (I)		Root-knot nematode (N)		Glomus (G)	
treatment -/+	-	+	-	+	-	+	-	+
no. of repetitons	48	48	48	48	48	48	48	48
Height of plant (cm)								
mean ± CI 95%	48 ± 1.6	55.9 ± 2	51.8 ± 1.9	52 ± 2.3	52.3 ± 1.8	51.6 ± 2.4	51.4 ± 2.3	52.4 ± 1.9
p-value	**< 0.001**		0.913		0.661		0.510	
Widest diameter of canopy (cm)								
mean ± CI 95%	74.7 ± 4.8	98.7 ± 5	86.9 ± 5.9	86.4 ± 6	84.1 ± 5.9	89.2 ± 5.9	87.2 ± 6.2	86.2 ± 5.7
p-value	**< 0.001**		0.904		0.234		0.828	
Fresh shoot weight (g)								
mean ± CI 95%	180.9 ± 16.6	321.6 ± 32.2	249.8 ± 32.8	252.8 ± 32.3	253.8 ± 32	248.7 ± 33	264.1 ± 36.2	238.4 ± 27.9
p-value	**< 0.001**		0.899		0.828		0.273	
Fresh root weight (g)								
mean ± CI 95%	30.4 ± 2.8	58.3 ± 6.1	46.7 ± 6.8	42 ± 5.4	42.8 ± 6.6	45.9 ± 5.8	45.9 ± 6.8	42.8 ± 5.6
p-value	**< 0.001**		0.304		0.501		0.501	

soil samples, including predatory nematodes.

Soil samples were used for measuring soil organic matter (Walkley 1947) and pH with distilled water and with potassium chloride (Buzás 1988). Samples were processed per plots.

Statistical methods

Welch test, correlation analysis and One-way ANOVA (Tukey's pairwise comparisons) were used for data analysis in "PAST" statistical software (Hammer et al. 2001).

Results and discussion

Only mulching had significant effect on all the measured parameters of tomato. It increased the maximum number of bunches, buds and flowers, and the total number of fruits. In addition, the maximum number of flowers was influenced by irrigation as well (Table 2). Mulched plants

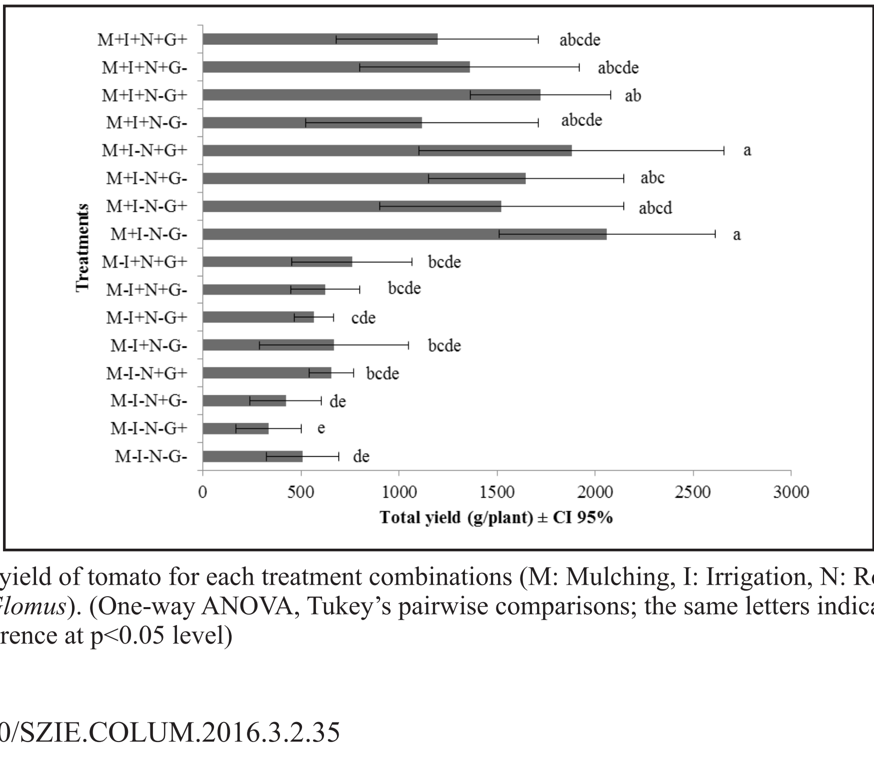

Figure 2. Total yield of tomato for each treatment combinations (M: Mulching, I: Irrigation, N: Root-knot nematode, G: *Glomus*). (One-way ANOVA, Tukey's pairwise comparisons; the same letters indicate the lack of significant difference at p<0.05 level)

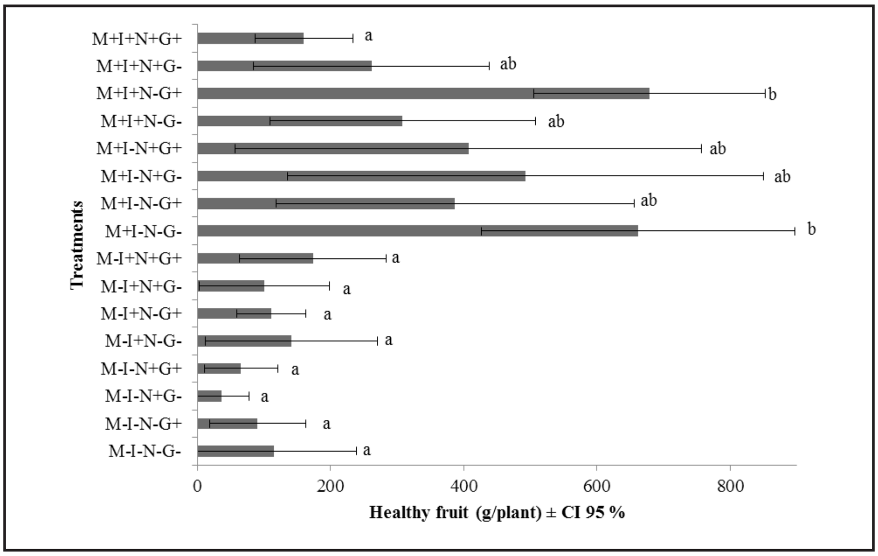

Figure 3. Healthy yield of tomato for each treatment combinations (M: Mulching, I: Irrigation, N: Root-knot nematode, G: *Glomus*). (One-way ANOVA, Tukey's pairwise comparisons; the same letters indicate the lack of significant difference at p<0.05 level)

grew higher and had wider canopies, even when compared to the irrigated unmulched treatment. The weight of fresh shoots and roots of plants were significantly higher in mulched plots (Table 3). It is in a line with the findings of Soltész (1997), who published that mulching increased nutrient uptake, and therefore the growth of plants as well.

The presence of mulch resulted in higher yields (Figure 2). The most healthy fruits were measured in two mulched, but non-infested treatment combinations (M+I-N-G- and M+I+N-G+) (Figure 3). Despite the fact that mulching increased the quantity of healthy fruits, it did not affect the percentage of damaged (infected by tomato late blight and/or damaged by cotton bollworm) fruits. This is in contrast with earlier data published by Shtienberg et al. (2010), who experienced a *Phytophthora*-reducing effect of mulching. In our results, the presence of leaf litter mulch influenced the quantity of yield more than the damage and presence of pests. While treatments had no effect on late blight symptoms or cotton bollworm damage, a negative correlation was found between the proportion of damaged fruits by cotton bollworm

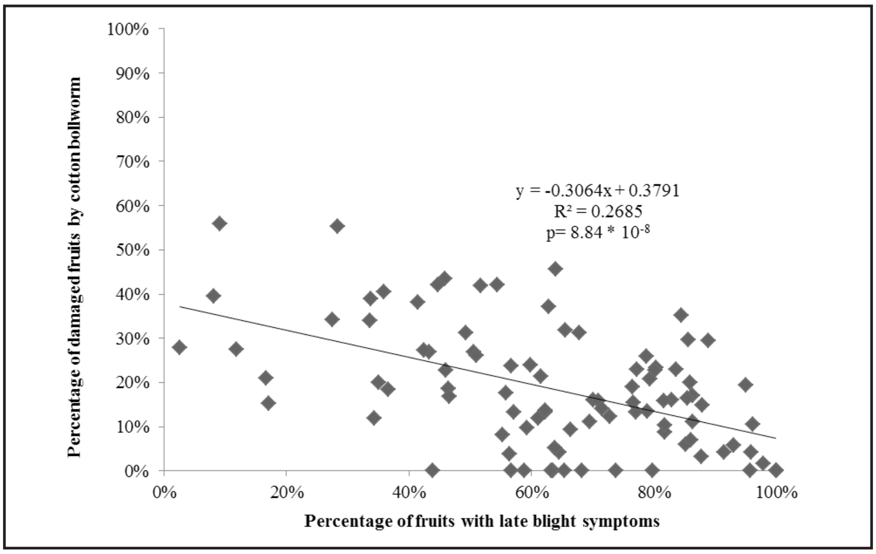

Figure 4. Correlation between percentage of tomato fruits damaged by cotton bollworm and percentage of fruits with late blight symptoms. (Each dot represents a tomato plant.)

 DOI: 10.18380/SZIE.COLUM.2016.3.2.35

Table 4. Values of soil organic matter and pH (with destillated water and potassium chloride), depending on mulching and irrigation. (p-value: Welch test)

	Mulching (M)		Irrigation (I)	
treatment -/+	-	+	-	+
number of repetitons	12	12	12	12
	organic matter content (%)			
mean ± CI 95%	2 ± 0.4	1.9 ± 0.6	2 ± 0.6	1.8 ± 0.4
p-value	0.819		0.626	
	pH with distilled water			
mean ± CI 95%	7.8 ± 0.1	7.8 ± 0.1	7.8 ± 0.1	7.9 ± 0.1
p-value	1.000		0.078	
	pH with potassium chloride (KCl)			
mean ± CI 95%	6.8 ± 0.1	6.8 ± 0.1	6.8 ± 0.01	6.8 ± 0.1
p-value	0.242		0.404	

Table 5. Estimation of root-knot nematode *(Meloidogyne incognita)* damage on the roots of unmulched and mulched (M), non-irrigated and irrigated (I), non-infested and artificially nematode-infested (N), non-inoculated and artificially mycorrhiza-inoculated (G) tomato plants with scales elaborated by Zeck (1971), Garabedian and Van Gundy (1984), Mukhtar et al. (2013) (modification of Taylor and Sasser 1978). (p-value: Welch test)

	Mulching (M)		Irrigation (I)		Root-knot nematode (N)		Glomus (G)	
treatment -/+	-	+	-	+	-	+	-	+
nof repetitons	48	48	48	48	48	48	48	48
	Zeck (0-10)							
mean ± CI 95%	1.77 ± 0.56	1.10 ± 0.38	1.44 ± 0.47	1.44 ± 0.5	0.44 ± 0.27	2.44 ± 0.49	1.63 ± 0.53	1.25 ± 0.43
p-value	0.056		1.000		**< 0.001**		0.285	
	Garabedian and Van Gundy (0-5)							
mean ± CI 95%	1.25 ± 0.49	0.60 ± 0.22	0.94 ± 0.41	0.92 ± 0.37	0.25 ± 0.16	1.60 ± 0.46	1.19 ± 0.47	0.67 ± 0.27
p-value	**0.022**		0.941		**< 0.001**		0.064	
	Mukhtar et al. (0-6)							
mean ± CI 95%	2.06 ± 0.7	0.91 ± 0.33	1.52 ± 0.58	1.46 ± 0.57	0.35 ± 0.23	2.63 ± 0.63	1.73 ± 0.64	1.25 ±0.5
p-value	**0.005**		0.881		**< 0.001**		0.248	

Figure 5. Predatory nematodes (1a: *Clarkus* sp., 2b: *Mylonchulus* sp.) found in the soil samples of tomato plots.

Table 6. Species of weed flora, their lifestyles and the percentage of weed covering for mulched (M+), unmulched (M-), irrigated (I+) and non-irrigated (I-) plots.

Species	Life forms	M- I-	M- I+	M+ I-	M+ I+
Stellaria media	T1	80	60	23	75
Elymus repens	G1	2	3	25	25
Chenopodium album	T4	11	20	5	6
Convolvulus arvensis	G3	8	6.5	10	20
Setaria viridis	T4	0.5	0.2	17	10
Setaria pumila	T4	1	0.5	15	5
Echinochloa crus-galli	T4	2	2	10	8
Glechoma hederacea	H2	4	2	10	1
Solanum tuberosum	G2	3	1	5	10
Taraxacum officinale	H3	3	8	10	3
Portulaca oleracea	T4	1	0.8	6	4
Amaranthus retroflexus	T4	0.1	0.4	1	5
Galinsoga parviflora	T4	1.3	0.5	5	5
Digitaria sanguinalis	T4	4	2.5	4	4
Acer spp.	Ph	0.2	3	1.5	2
Capsella bursa-pastoris	T1	2	0	0	0
Conyza canadensis	G1	0	0	0	2
Polygonum aviculare	T4	1.5	0.3	2	0.2
Solanum nigrum	T4	0	0	0.5	2
Humulus lupulus	H3	0	0.2	0	1.5
Oxalis corniculata	H2	1	0.1	0	0
Amaranthus chlorostachys	T4	0	0	0.5	0
Ambrosia artemisiifolia	T4	0	0.5	0	0
Daucus carota	T4	0.5	0.2	0	0
Lamium purpureum	T1	0.5	0.1	0	0
Anagallis arvensis	T4	0.2	0.4	0.2	0.4
Ailanthus altissima	Ph	0	0	0	0.3
Artemisia vulgaris	H5	0	0.2	0	0
Chelidonium majus	H5	0.1	0	0.2	0
Stenachtis annua	T4	0.2	0.1	0	0
Ballota nigra	H5	0	0	0	0.1
Lolium perenne	H1	0	0	0	0.1
Medicago lupulina	T4	0.1	0.1	0	0
Raphanus raphanistrum	T3	0	0.1	0	0
Solanum nigrum	T4	0	0.1	0	0

and proportion of fruits with the symptoms of late blight (Figure 4), probably because female moths preferred uninfected fruits for egg-laying.

According to the literature, irrigation increased (Karajeh and Mohawesh 2016) and mycorrhiza-inoculation decreased (Diedhiou et al. 2003) the number of *Meloidogyne*-induced galls on the roots. We did not experience these effects in our trial, probably due to the weather conditions of the year of the experiment. Results of next years with the same experimental design may answer this question. In our experiment, leaf litter mulching decreased the damage of root-knot nematodes, similarly to the results of Forge et

 DOI: 10.18380/SZIE.COLUM.2016.3.2.35

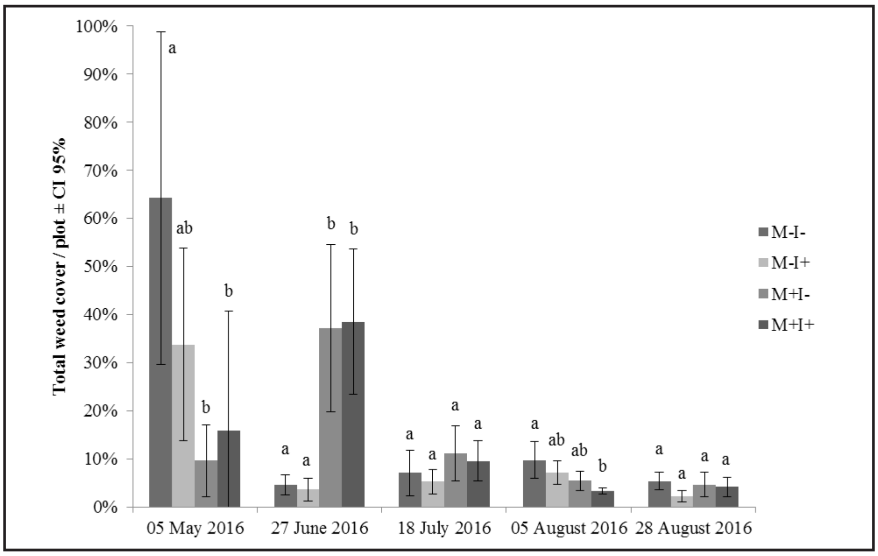

Figure 6. Change of total weed cover in tomato plots receiving the following treatments: mulched and unmulched (M+ and M-), irrigated and non-irrigated (I+ and I-). (One-way ANOVA, Tukey's pairwise comparisons; the same letters within a group of columns of the same date indicate the lack of significant difference at p<0.05 level)

al. (2008), who used newspaper mulch against *Pratylenchus penetrans*, or Ogwulumba and Ugwuoke (2011), who used plastic mulch against *Meloidogyne javanica*. Although these three experiments used totally different mulch materials, the results were highly similar. This may suggest that nematode-suppression of mulch is mainly not due to chemical changes in the soil, but rather to physical or biological changes.

Neither mulching, nor irrigation influenced soil organic matter content and pH (measured with distilled water and with potassium chloride) (Table 4). Considering the fact that mulch was spread in the spring, therefore it had probably not enough time to influence these soil parameters yet. So these parameters cannot explain the reduced *Meloidogyne*-symptoms and increased yield in the mulched plots compared to the unmulched control. The experiment is going to be continued exactly at the same place with the same experimental design next years, so as many parameters as possible, like tannin content and nutrient content of mulch and soil should be measured periodically in the future.

During the species identification of root-knot nematodes, only *Meloidogyne incognita* individuals were observed. This result met our expectations as inoculum was collected from a polytunnel. Mulching reduced the damage of root-knot nematodes (Table 5). As *M. incognita* is a thermophilic nematode species (Andrássy and Farkas 1988), we assume that the circumstances (like temperature) in the mulched soil were not preferable to this species. We plan to test the native *M. hapla* species next year in a similar experiment. Another hypothesis for the explanation of the reduced *M. incognita* infestation in the mulched plots is the increased presence of antagonist organisms of root-knot nematodes. However, neither the density of other nematodes in the soil, nor the number of predatory nematodes was influenced by treatments. Two predatory nematode genera were found: *Clarkus* and *Mylonchulus* (Figure 5). Distribution of predatory nematodes was random which is in line with earlier data published by Renčo and Kováčik (2012). So we cannot explain reduced *Meloidogyne* damage on the roots of the mulched plants with the presence and density of potential antagonist nematodes in our experiment.

In the first two weed surveys, at the beginning of the growing season, mulched and unmulched plots showed significant difference in weed cover by different reasons. At the first survey, unmulched plots were highly covered by chickweed (*Stellaria media*). At the second survey, the mulched plots were weedier mainly

DOI: 10.18380/SZIE.COLUM.2016.3.2.35

caused by the high presence of field bindweed (*Convolvulus arvensis*) which can be poorly controlled in a thick mulch layer. Later, there was no difference between the weed cover of the treatments, probably because of the decomposition of the leaf litter and because of the germination and reproduction biology of the dominant weed species (Table 6, Figure 6).

Conclusions

Our results suggest that the effect of leaf litter mulch should be subjected to further studies. Application of leaf litter mulch had a significant positive effect on tomato yield and on the generative and vegetative parameters of the plant. Mulching reduced *Meloidogyne*-infestation, but did not influence *Phytophthora infestans* infection and *Helicoverpa armigera* damage. It should be tested in the future whether the leaf litter mulch provides matrix for other tomato pests, or beneficial organisms, like antagonists of root-knot nematodes. Suppression of weeds was experienced only at the beginning of the growing season, so repeated application of leaf litter mulch should be tested next years, extended with survey of composition – especially nutrient content and allelopathic substance content – of different leaf litter types.

Acknowledgements

The authors would like to express their thanks to students and colleagues, who helped in the field and laboratory work and to Zöld Híd Régió Ltd. for providing our experiment with leaf litter mulch. We are thankful for the support through the New National Excellence Program of the Ministry of Human Capacities and for the support of the Research Centre of Excellence - 1476-4/2016/FEKUT.

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